PATENT

Serial No. 10/646,018

Docket No. JSF01-0054D1/WJT08-0005D1

AMENDMENTS

IN THE SPECIFICATION

Please replace the paragraph containing the "CROSS REFERENCE TO RELATED PATENT APPLICATION" section beginning at page 1, line 1 as follows:

> This application is a divisional application of United States Patent Application No. 09/644,019, filed August 22, 2000, <u>now issued as US Patent No. 6,646,522</u>, which claims the benefit of United States Provisional Application Serial No. 60/150,618, filed August 24, 1999.

Please replace the paragraph beginning on page 3, line 21 as follows:

--United States Patents No. 5,472,935 and 6,078,827 disclose coplanar waveguides in which conductors of high temperature superconducting material are mounted on a tunable dielectric material. The use of such devices requires cooling to a relatively low temperature. In addition, United States Patents No. 5,472,935 and 6,078,827 teach the use of tunable films of $SrTiO_3$, or (Ba, Sr)TiO_3 with high a ratio of Sr. ST and BST have high dielectric constants, which results in low characteristics impend[e]<u>a</u>nce. This makes it necessary to transform the low impend[e]<u>a</u>nce phase shifters to the commonly used 50 ohm impedance.--

Please replace the paragraph beginning on page 6, line 8 as follows:

--FIG. 1 is a top plan view of a reflective phase shifter constructed on <u>a tunable dielectric layer 46</u> in accordance with the present invention. FIG. 2 is a cross-sectional view of the phase shifter of FIG. 1, taken along line 2-2. The embodiment of FIGs. 1 and 2 is a 20 GHz K band 360°

relabel
to
approp figs

reflective coplanar waveguide phase shifter 10. The phase shifter 10 has an input/output 12 connected to a 50-ohm microstrip line 14. The 50-ohm microstrip line 14 includes a first linear line 16 and two quarter-wave microstrip lines 18, 20, each with a characteristic impedance of about 70 ohm. The microstrip line 14 is mounted on a substrate 22 of material having a low dielectric constant. The two quarter-wave microstrip lines 18, 20 are transformed to coplanar waveguides (CPW) 24 and 26 and match the line 16 to coplanar waveguides 24 and 26. Each CPW includes a center strip line 28 and 30 respectively, and two conductors 32 and 34 forming a ground plane 36 on each side of the strip lines. The ground plane conductors are separated from the adjacent strip line by gaps 38, 40, 42 and 44. The coplanar waveguides 24 and 26 have a characteristic impedance of about Z24 = 15 Ohms and Z26 = 18 ohms, respectively (as shown in FIG. 3). The difference in impedances is obtained by using strip line conductors having slightly different center line widths. The coplanar waveguides 24 and 26 work as resonators. Each coplanar waveguide is positioned on a tunable dielectric layer 46 (shown in FIG. 2). The conductors that form the ground plane are connected to each other at the edge of the assembly. The waveguides 24 and 26 terminate at open ends 48 and 50.--

Please replace the paragraph beginning on page 8, line 11 as follows:

--The K and Ka band coplanar waveguide phase shifters of the preferred embodiments of this invention are fabricated on a tunable dielectric film with a dielectric constant (permittivity) ε of around 300 to 500 at zero bias and a thickness of 10 micrometer. However, both thin and thick films of the tunable dielectric material can be used. The film is deposited on a low dielectric constant substrate MgO only in the CPW area with thickness of 0.25 mm. For the purposes of this description a low dielectric constant is less than 25. MgO has a dielectric constant of about 10. However, the substrate can be other materials, such as $LaAlO_3$, sapphire, $A1_2\theta O_3$ and other ceramics. The thickness of the film of tunable material can be adjusted from 1 to 15 micrometers depending on deposition methods. The main requirements for the substrates are their chemical

stability, reaction with the tunable film at film firing temperature (~1200 C), as well as dielectric loss (loss tangent) at operation frequency.--

Please replace the paragraph beginning on page 8, line 23 as follows:

--FIG. 4 is a top plan view of a 30 GHz coplanar waveguide phase shifter assembly 60 constructed in accordance with this invention. FIG. 5 is a cross-sectional view of the phase shifter assembly 60 of FIG. 4, taken along line 5-5. Phase shifter assembly 60 is fabricated using a tunable dielectric film and substrate similar to those set forth above for the phase shifter of FIGs. 1 and 2. Referring to FIG. 4, a Assembly 60 includes a main coplanar waveguide 62 including a center line 64 and a pair of ground plane conductors 66 and 68 separated from the center line by gaps 70 and 72. The center portion 74 of the coplanar waveguide has a characteristic impedance of around 20 ohms. Two tapered matching sections 76 and 78 are positioned at the ends of the waveguide and form impedance transformers to match the 20-ohm impedance to a 50-ohm impedance. Coplanar waveguide 62 is positioned on a layer of tunable dielectric material 80. Conductive electrodes 66 and 68 are also located on the tunable dielectric layer and form the CPW ground plane. Additional ground plane electrodes 82 and 84 are also positioned on the surface of the tunable dielectric material 80. Electrodes 82 and 84 <u>are adjacent to tunable dielectric material 80</u>~~also extend around the edges of the waveguide~~ as shown in FIG. 5. Electrodes 66 and 68 are separated from electrodes 82 and 84 respectively by gaps 86 and 88. Gaps 86 and 88 block DC voltage so that DC voltage can be biased on the CPW gaps. For dielectric constant ranging from about 200 to 400 and an MgO substrate, the center line width and gap are about 10 to 60 micrometers. Referring to FIG 5, the The tunable dielectric material 80 is positioned on a planar surface of a low dielectric constant (about 10) substrate 90, which in the preferred embodiment is MgO with thickness of 0.25 mm. However, the substrate can be other materials, such as $LaAlO_3$, sapphire, Al_2~~O~~<u>O</u>$_3$ and other ceramic substrates. A metal holder 92 extends along the bottom and the sides of the waveguide. A bias voltage source 94 is connected to strip 64 through inductor 96.--

PATENT

Serial No. 10/646,018

Docket No. JSF01-0054D1/WJT08-0005D1

Please replace the paragraph beginning on page 9, line 23 as follows:

--FIG. 6 shows a 20 GHz coplanar waveguide phase shifter 98, which has a structure similar to that of FIGs. 4 and 5. However, a zigzag coplanar waveguide 100 having a central line 102 is used to reduce the size of substrate. FIG. 7 is a cross-sectional view of the phase shifter of FIG. 6, taken along line 7-7<u>[.] and includes 50-ohm microstrip line 14 which further includes a first linear line 16 and two quarter-wave microstrip lines 18, 20, each with a characteristic impedance of about 70 ohm. The microstrip line 14 is mounted on a substrate 22 of material having a low dielectric constant. The two quarter-wave microstrip lines 18, 20 are transformed to coplanar waveguides (CPW) 24 and 26 and match the line 16 to coplanar waveguides 24 and 26.</u> ? The waveguide line 102 of FIG. 6 ? has an input 104 and an output 106, and is positioned on the surface of a tunable dielectric layer 108. Referring to FIGS 6 and 7, a A pair of ground plane electrodes 110 and 112 are also positioned on the surface of the tunable dielectric material and separated from line 102 by gaps 114 and 116. The tunable dielectric layer 108 is positioned on a low loss substrate 118 similar to that described above. The circle near the middle of the phase shifter is a via 120 for connecting ground plane electrodes 110 and 112.-- as shown in FIG. 1

Please replace the paragraph beginning on page 10, line 3 as follows:

--FIG. 8 is a top plan view of the phase shifter assembly 42 of FIG. 4 with a bias dome 130 of FIG. 9 added to connect the bias voltage to ground plane electrodes 66 and 68. <u>As seen in FIG. 8, a 30 GHz coplanar waveguide phase shifter assembly 60 is constructed in accordance with this invention. Two tapered matching sections 76 and 78 are positioned at the ends of the waveguide and form impedance transformers to match the 20-ohm impedance to a 50-ohm impedance. Coplanar waveguide 60 is positioned on a layer of tunable dielectric material 80. FIG. 8 further illustrates an electrode termination 132 (also depicted in FIG. 9).</u> FIG. 9 is a cross-sectional view

of the phase shifter assembly 60 of FIG. 8, taken along line 9-9[.] <u>illustrating coplanar waveguide 60 positioned on a layer of tunable dielectric material 80. The tunable dielectric material 80 is positioned on a planar surface of a low dielectric constant (about 10) substrate 90. A metal holder 92 extends along the bottom and the sides of the waveguide.</u> Referring to FIG. 8, the dome 130 of FIG. 9 connects the two ground planes of the coplanar waveguide, and covers the main waveguide line. An electrode termination 132 of FIG. 9 is soldered on the top of the dome 130 to connect to the DC bias voltage control. Another termination (not shown) of the DC bias control circuit is connected to the central line 64 of the coplanar waveguide. In order to apply the bias DC voltage to the CPW, small gaps 86 and 88 (shown in FIG. 8 as a top plan view and FIG. 9 as a cross section view) are made to separate the inside ground plane electrodes 66 and 68, where the DC bias dome 130 is located, to the other part (outside) of the ground plane (electrodes 82 and 84, shown in FIG. 8 as a top plan view and FIG. 9 as a cross section view) of the coplanar waveguide. The outside ground plane extends around the sides and bottom plane of the substrate. Referring to FIG. 9, the outside or the bottom ground plane is connected to an RF signal ground plane 134. The positive and negative electrodes of the DC source are connected to the dome 130 and the center line 64, respectively. The small gaps in the ground plane work as DC blocking capacitors, which block DC voltage. However, the capacitance should be high enough to allow passage of an RF signal through it. The dome 130 electrically connects ground planes 66 and 68. The dome 130 connection should be mechanically strong enough to avoid touching other components. It should be noted that the widths of ground planes 66 and 68 are about 0.5 mm in this example.--

Please replace the paragraph beginning on page 10, line 25 as follows:

--A microstrip line and the coplanar waveguide line can be connected to one transmission line. FIG. 10 is a top plan view of another phase shifter 136 constructed in accordance with the present invention. FIG. 11 is a cross-sectional view of the phase shifter of FIG. 10, taken along line 11-

11. FIGs. 10 ~~and 11~~ shows how the microstrip 138 line transforms to the coplanar waveguide assembly 140. Referring to FIG. 10, the microstrip 138 includes a conductor 142 (top plan view in FIG. 10 and cross section view in FIG. 11) mounted on a substrate 144 (top plan view in FIG. 10 and cross section view in FIG. 11). The conductor 142 (top plan view in FIG. 10 and cross section view in FIG. 11) is connected, for example by soldering or bonding, to a central conductor 146 (top plan view in FIG. 10 and cross section view in FIG. 11) of coplanar waveguide 148 (top plan view in FIG. 10~~ and cross section view in FIG. 11~~). Ground plane conductors 150 (FIG. 10) and 152 (FIG. 10) are mounted on a tunable dielectric material 154 (top plan view in FIG. 10 and cross section view in FIG. 11) and separated from conductor 146 (top plan view in FIG. 10 and cross section view in FIG. 11) by gaps 156 and 158 of FIG. 10. In the illustrated embodiment, solder 160 (top plan view in FIG. 10 and cross section view in FIG. 11) connects conductors 142 and 146 (top plan view in FIG. 10 and cross section view in FIG. 11). Referring to FIG. 11, the tunable dielectric material 154 is mounted on a surface of a non-tunable dielectric substrate 162. Substrates 144 and 162 (top plan view in FIG. 10 and cross section view in FIG. 11, respectively) are supported by a metal holder 164 (FIG. 11).--

Please amend the paragraph beginning on page 11, line 23 as follows:

--FIG. 13 is an exploded isometric view of an array 170 of 30 GHz coplanar waveguide phase shifters constructed in accordance with the present invention, for use in a phased array antenna. A bias line plate 172 is used to cover the phase shifter array. The electrodes on the dome of each phase shifter are soldered to the bias lines on the bias line plate through the holes 174, 176, 178 and 180. The phase shifters are mounted in a holder 182 that includes a plurality of microstrip lines 184, 186, 188, 190, 192, 194, 196 and 198 for connecting the radio frequency input and output signals to the phase shifters. The particular structures shown in FIG. 13, provide each phase shifter with its own protective housing. The phase shifters are assembled and tested individually before being installed in the phased array antenna. This significantly improves yield

of the antenna, which usually has tens to thousands phase shifters. <u>Again, a housing 166 is built over the bias dome to cover the whole phase shifter such that only two 50 ohm microstrip lines are exposed to connect to an external circuit.--</u>

Please replace the paragraph beginning on page 12, line 18 as follows:

--The preferred embodiments of the present invention provide coplanar waveguide phase shifters, which include a BST-based composite thick film having a tunable permittivity. These coplanar waveguide phase shifters do not employ bulk ceramic materials as in the microstrip ferroelectric phase shifters above. The bias voltage of the coplanar waveguide phase shifter on film is lower than that of the microstrip phase shifter on bulk material. The thick film tunable dielectric layer can be deposited by standard thick, film process onto low dielectric loss and high chemical stability subtracts, such as MgO, $LaAlO_3$, sapphire, Al_2~~0~~<u>O</u>$_3$, and a variety of ceramic substrates.--